National Aeronautics and Space Administration

technology opportunity

Multi-Mode Guided Wave Scanning System

Detects hidden defects in composite materials

Researchers at NASA Glenn Research Center have developed an ultrasonic scan system to detect degradation in ceramic matrix composites and polymer matrix composites. The scanner reveals micro-damage in composite materials that, on the surface, do not appear to have any flaws. Employing the guided-wave method, the scanner can be used in a single-point or conventional scanning mode, and can inspect even mildly curved surfaces.

Benefits

- **Detects a wide variety of structural defects:**
  - — Delamination
  - — Crack spaces
  - — Density variation
  - — Oxidation damage
  - — Elastic properties
  - — Microstructural changes
- **Provides directional performance.** Allows correlations to be made between ultrasonic parameters and directionally dependent properties, including through velocity measurement.
- **Uses dry coupling.** Alleviates need to immerse material in fluid.
- **Allows precision.** Is load-controllable for consistent coupling from scan point to scan point.
- **Offers versatility.** Works on components with mildly curved surfaces; characterizes local modulus changes without requiring nodal excitation and generation.
- **Affords flexibility.** Presents more choices in signal processing parameters and images to be calculated.
- **Accommodates immediate monitoring.** Enables quick decisions on microstructural quality as the scan progresses.

Applications

This technology provides non-destructive testing/inspection and materials evaluation/characterization (NDI/NDT/NDE) of virtually any material, but it is particularly suited for ceramic matrix composites (CMCs) and polymer matrix composites (PMCs), both of which are widely used commercially for the following items:

- Automobiles
- Aircraft—Boeing 787, Airbus 380
- Aerospace—heat shields
- Sporting goods—tennis racquets, golf clubs
- Storage and processing tanks—fuel, chemical, cryogenic liquids
- Pipes and tubes—pipelines, culverts

Technology Details

How It Works

The ultrasonic guided wave scan system is composed of customized hardware and software that allows repeated single-point measurement or scan methods. The system uses broadband ultrasonic guided waves in a precision, dry-coupled manner to detect microdamage in difficult-to-inspect composite materials. The system is controlled via motorized stages in two directions (X- and Y-) and pneumatically in a third (Z-, or up and down) direction. The software controls motion and data acquisition, the latter for a high-speed analog-to-digital converter. The data analysis method relies heavily on advanced signal processing, developed to deconvolve the information garnered by the multiple modes of ultrasound.

The system uses two ultrasonic transducers: one transmits the ultrasonic energy and the other receives the modulated ultrasonic signals returned. The system scans the material in an orderly, automated, computer-controlled fashion over an array of scan points. The software performs real-time analysis, in both time and frequency domains, of the multi-mode ultrasonic response to simultaneously form up to 18 images. Users can choose from 30 parameters with 18 to display.

What Makes It Better

Historically, failure mechanisms of composites (widespread matrix cracking and fiber-matrix separation) have been difficult to characterize by conventional ultrasonic scanning and other nondestructive evaluation methods. This new guided wave scanning method offers a unique approach, utilizing the total ultrasonic response rather than attempting to develop customized transducers that exhibit one or two modes. The system utilizes specialized signal processing routines to extract parameters of the time- and frequency-domain signals. Performed directionally, the scanning method allows the user to make correlations between ultrasonic parameters and directionally dependent material properties, for use with unidirectional composites and to test the non-directionality of the properties.

User choice of imaging parameters enables maximum material applicability, and real-time analysis allows ongoing decision-making while the scan is in process. This method promises to characterize, evaluate, and detect defects and global microstructural damage such as matrix microcracking in CMCs and PMCs.

The system characterizes samples for material homogeneity, microstructural condition, pervasive microdamage, and large discrete flaws. As such, it has potential for composite, ceramic, metallic, and polymeric plate-like structures. The system can determine the quality of body panels and engine materials, inspect building materials in critical loading applications, and detect oxidation damage in reinforced carbon-carbon (RCC) materials for which single-sided inspection methods are critical.

A user manual and hardware schematics are available to facilitate the technology transfer to academic institutions and industrial entities.

Partnering Opportunities

NASA invites companies to discuss partnering opportunities for commercial applications of this innovative scanner.

For More Information

For more information about this and other licensing/partnering opportunities, please visit:

Technology Transfer and Partnership Office
NASA Glenn Research Center
E-mail: ttp@grc.nasa.gov
Phone: 216–433–3484
http://technology.grc.nasa.gov/